TARDEC

Technical Report

No. 13620

Compatibility of Single Hydraulic Fluid with Military Specification Fluids, Seals and Metallurgy

March 1995

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Mobility Technology Center Belvoir

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Research, Development and Engineering Center
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Section 1 Introduction and Background

The Army currently uses three military specification hydraulic fluids for its ground equipment; MIL-H-6083 (OHT); MIL-H-46170 (FRH); and MIL-H-5606 (OHA).[1,2,3] In The US Army currently relies on three different hydraulic fluids for its ground equipment. MIL-H-5606 (OHA) and MIL-H-6083 (OHT) are both petroleum base fluids with excellent low temperature operability, but poor fire resistance. MIL-H-46170 (FRH) is a synthetic hydrocarbon based hydraulic fluid with excellent fire resistance but poor low temperature performance.[1,2,3] Since none of the three fluids provide all desired characteristics for military purposes, the US Army Mobility Technology Center - Belvoir developed a modified fire resistant hydraulic fluid, designated Single Hydraulic Fluid (SHF), which exhibits satisfactory low temperature operability. This fluid has met all target performance requirements in the laboratory (see Table 1) and offers every indication of replacing the three currently used fluids.

Table 1. Requirements for Desirable Military Hydraulic Fluid

PERFORMANCE TEST	MIL-L-46170	SHF
Oxidation/Corrosion ASTM D4636, #3	168 hrs @ 121°C vis. < 10%	168 hrs @ 135°C vis. < 10%
Corrosion Inhibition ASTM D1748	100 hrs min	100 hrs min
Galvanic Corrosion FTM 5322	10 days min	10 days min
Low Temp Stability FTM 3458	72 hrs @ -54°C	72 hrs @ -54°C
Pour Point ASTM D97	-60°C min	-60°C min
Viscosity @ 40°C ASTM D445	19.5 cSt max	19.5 cSt max
Viscosity @ 100°C ASTM D445	3.4 cSt min	2.5 cSt min
Viscosity @ -40°C ASTM D445	2600 cSt max	800 cSt max
Viscosity @ -54°C ASTM D445	report	3500 cSt max
Solid particle Count MIL-H-46170	10,000 max @ 5-25 micrometers	10,000 max @ 5-15 micrometers
Solid Particle Count MIL-H-46170	250 max @ 26-50 micrometers	1,000 max @ 16-25 micrometers
Solid Particle Count MIL-H-46170	50 max @ 51-100 micrometers	150 max @ 26-50 micrometers
Solid Particle Count MIL-H-46170	10 max @ over 100 micrometers	20 max @ 51-100 micrometers

Table 1. Requirements for Desirable Military Hydraulic Fluid (continued)

PERFORMANCE TEST	MIL-L-46170	SHF
Solid Particle Count MIL-H-46170		5 max @ over 100 micrometers
Acid Number ASTM D664	0.2 gm KOH/gm max	0.3 gm KOH/gm max
Elastomer Swell FTM 3603	15% - 25%	19% - 28%
Evaporation Loss ASTM D972	5% max	35% max
Steel on Steel Wear ASTM D4172	0.3 mm max @ 10 kg load	0.3 mm max @ 10 kg load
Steel on Steel Wear ASTM D4172	0.65 mm max @ 40 kg load	0.65 mm max @ 40 kg load
Foam Characteristics ASTM D892	65 ml max	65 ml max
Water Content ASTM D1744	500 ppm max	100 ppm max
Flash Point ASTM D92	219°C min	180°min
Fire Point ASTM D92	246°C min	190°C min
Autoignition Temp ASTM E659	343°C min	325°C min
Hi Temp/Hi Press Ignt FTM 6052	no continuation of burning when ignition source is removed	no continuation of burning when ignition source is removed
Flame Propagation MIL-H-83282	0.3 cm/sec max	0.3 cm/sec max
Storage Stability FTM 3465	12 months	12 months

To insure that the developmental SHF can successfully be fielded in Army ground equipment, compatibility with existing systems must be assured. Because SHF is intended as a one-to-one replacement for currently used fluids, it must be compatible not only with the metallurgy and elastomeric seals in the hydraulic systems but also with any residual hydraulic fluid that remains after conversion. To demonstrate this compatibility, SHF was subjected to varying amounts of fluid "contamination" with OHT and FRH, and tested in the presence of elastomeric materials and metals commonly used in hydraulic system components. OHA was not used as a test fluid as it is chemically identical to OHT except that it does not contain a corrosion inhibitor. IF SHF demonstrates compatibility with OHT it will be compatible with OHA.

Section 2 Technical Approach

To demonstrate compatibility with existing fluids and seals, the investigation was conducted in three parts. First, all three fluids were subjected to elastomer swell testing with the elastomer samples of fluorosilicone (FVMC), polyurethane (AU), nitrile (NBR), polyacrylate (ACM), and fluorocarbon (CFM). The elastomers were tested for volume swell and hardness before and after a 168 hour soak in the test fluid at 70°C.[4] This established an initial baseline of performance for each fluid in the presence of the elastomers (see Table 2, page 4).

For the next phase, the elastomer samples from the FRH and OHT fluids were subjected to an additional 168 hour soak in SHF. Testing the elastomers in SHF after they have already been subjected to FRH or OHT provides an indication of how the seals in hydraulic systems will be affected after they have been changed over from FRH or OHT to SHF. This investigation is intended to determine if any excessive swelling, loss of volume swell, or deterioration occurs in the elastomers after they have experienced subsequent exposure to SHF. If no major changes in the elastomers occur upon exposure to SHF after previous exposure to OHT or FRH, fluid/elastomer compatibility will be partly established.

A final demonstration of fluid/elastomer compatibility involves treating SHF with varying concentrations of FRH and OHT. Samples of SHF were prepared that contained 1%, 3%, 5%, 10% and 15% FRH and OHT, thus a total of ten test fluids were subjected to the elastomer materials. Contaminating SHF with FRH and OHT simulates the conditions expected after a flush and fill conversion of a vehicle using FRH or OHT. If no excessive swelling, loss of volume swell, or deterioration of the elastomers occurs upon exposure to these mixed fluid samples, SHF will have truly demonstrated fluid and seal compatibility.

To demonstrate full compatibility with Army hydraulic systems, SHF was tested in the presence of both the elastomer materials and component metals. The metals used in testing were steel, cadmium, copper, magnesium, and aluminum. These metals are specified in FTM-791-5308, Corrosiveness and Oxidation Stability of Light Oils (Metal Squares).

Section 3. Results

Baseline testing was accomplished by following FTM-791 Method #3603, Swelling of Synthetic Rubbers, for each of the test fluids. Table 2 summarizes the volume swell and seal hardness for each fluid and elastomer.

Table 2. Baseline Elastomer Compatibility

Seal	SHF			OHT			FRH		
	V%	HD_i	HD_f	V%	HD_i	HD_f	V%	HD_i	HD_f
FVMC	3.0	15	15	4.5	15	16	1.2	15	16
AU	1.0	22	22	1.2	22	22	0.6	22	23
NBR	3.0	20	19	6.1	20	19	1.5	20	21
ACM	3.3	18	16	5.8	18	17	1.7	18	17
CFM	0.7	26	25	0.7	25	22	0.6	26	22

Key: V% = Volume Swell
HDi = Initial Hardness
HDf = Final Hardness

As can be seen from the above data, OHT causes the seal materials to swell significantly more than FRH except for the fluorocarbon samples. OHT is also more proficient at seal swell than SHF for the test materials, although SHF provides more seal swell than FRH. For the fluorosilicone, polyurethane, and fluorocarbon materials, SHF provides sufficient seal swell to be comparable to OHT in performance even though SHF is slightly on the low side. The nitrile and polyacrylate materials, however, indicate a wider discrepancy between the OHT performance and SHF performance. It is not known if this discrepancy is significant enough to cause a difference in performance of the seals in actual vehicles. Table 2 also indicates the different effects the fluids have on seal hardness.

While the above baseline data allows some direct comparisons to be drawn from the fluids' effect on the elastomers, it does not give an indication of how SHF will perform in a vehicle that has been previously exposed to FRH or OHT. To pursue this question, sequential rubber swell tests were conducted. The same elastomer samples that yielded the above data were re-tested in SHF for an additional 168 hours. This type of sequential testing does not follow a standard test methodology in that submerging an elastomer previously subjected to an initial fluid in a second fluid has never been previously reported in literature. The same procedure for determining elastomer swell (FTM-791 Method #3603) was used on the already swelled elastomer sample, thus a logical methodology was utilized in obtaining this data. Table 3 provides the results of these subsequent exposures.

Table 3. Sequential Elastomer Swell

SEAL	SHF	OHT	OHT/SHF	FRH	FRH/SHF
FVMC	3.0%	4.5%	-16.8%	1.2%	-19.2%
AU	1.0%	1.2%	1.1%	0.6%	1.1%
NBR	3.0%	6.1%	3.9%	1.5%	3.9%
ACM	3.3%	5.8%	4.6%	1.7%	3.3%
CFM	0.7%	0.7	0.9%	0.6%	1.1%

Key: OHT/SHF = Final volume swell of elastomer sample after exposure to OHT then sequential exposure to SHF

FRH/SHF = Final volume swell of elastomer sample after exposure to FRH then sequential exposure to SHF

The data in Table 3 indicates the final state of the elastomer samples. By comparing columns 2, 3, and 4, it can be seen that except for the two fluoro elastomers, the subsequent immersion of the samples into SHF yielded a final swell which is greater than that achieved by SHF alone, yet less than what was originally exhibited after immersion in OHT. A comparison of columns 2, 5, and 6 indicates the situation is slightly different for the FRH/SHF samples. Except for the fluorosilicone, each elastomer sample exhibited seal swell equivalent to or greater than the swell achieved with SHF alone. The fluorocarbon samples exhibited a slight increase in swell for both OHT and FRH, but since the numbers are so close, it cannot actually be concluded that fluorocarbon increases in swell after subsequent exposure to SHF. The change in seal swell is not significant enough to be outside the "noise" of the test methodology. The results of the fluorosilicone test, however, are an anomaly. The test was repeated after the results indicated severe loss of seal swell, but the numbers were verified in the second test. This investigation has not pursued an explanation as to the chemistry between the fluids and fluorosilicone. At this time it can only be concluded that SHF is not compatible with a fluorosilicone seal that has previously been exposed to either FRH or OHT. If the fluorosilicone seal is brand new, it can be used with SHF with no risk of incompatibility or deterioration.

The next investigation into fluid/elastomer compatibility involved testing the SHF contaminated with varying concentrations of FRH and OHT. Tables 4 and 5 give the results of these tests. In addition to determining the volume swell of the elastomers, the mixed fluid viscosities, and flash and fire points were also determined.

Table 4. Elastomer Swell of SHF Contaminated with FRH

SEAL	SHF	1%FRH	3%FRH	5%FRH	10%FRH	15%FRH
FVMC	3.0%	2.6%	3.1%	2.6%	2.1%	2.2%
AU	1.0%	2.6%	1.4%	1.4%	1.0%	1.5%
NBR	3.0%	3.5%	3.6%	3.7%	3.1%	4.1%
ACM	3.3%	1.2%	3.1%	2.4%	2.2%	3.7%
CFM	0.7%	0.6%	0.2%	0.9%	0.3%	0.2%
VIS @ 40°C	10.2cSt	10.2cSt	10.4cSt	10.8cSt	10.9cSt	11.6cSt
VIS @100°C	2.8cSt	3.1cSt	3.0cSt	3.2cSt	3.2cSt	3.0cSt
Flash Point	184°C	186°C	186°C	188°C	188°C	190°C
Fire Point	202°C	196°C	196°C	204°C	204°C	206°C

Contamination of SHF with FRH from 1% to 15% results in little significant change in the elastomer swell. The addition of 15% FRH yields a change of only 1% increase in swell for the nitrile elastomer and a 1% decrease in swell for the fluorosilicone elastomer samples. This amount of FRH in SHF does have a some impact, however, on the fluid properties. Note from Table 4 that the flash point has increased to 190°C and the fire point has increased to 206°C. The viscosities remain relatively unaffected.

Addition of OHT to SHF also produced some minor effects. Volume swell for the nitrile sample showed a slight increase with the addition of OHT while the fluorocarbon exhibited a slight decrease. The most significant change occurred in the loss of fire and flash point. Addition of 15% OHT dropped the flash point to 156°C and the fire point to 170°C. Again, the viscosities remain relatively unchanged.

Table 5. Elastomer Swell of SHF Contaminated with OHT

SEAL	SHF	1%OHT	3%OHT	5%OHT	10%OHT	15%OHT
FVMC	3.0%	2.9%	2.6%	2.7%	2.8%	2.8%
AU	1.0%	1.4%	1.6%	1.4%	1.4%	1.4%
NBR	3.0%	4.3%	3.7%	3.8%	4.2%	3.6%
ACM	3.3%	2.9%	2.9%	3.3%	3.2%	3.3%
CFM	0.7%	0.8%	0.5%	0.5%	0.5%	0.5%
VIS @ 40°C	10.2cSt	10.5cSt	10.6cSt	10.6cSt	10.7cSt	11.2cSt
VIS @ 100°C	2.8cSt	3.4cSt	3.4cSt	3.5cSt	3.5cSt	3.8cSt
Flash Point	184°C	182°C	172°C	168°C	162°C	156°C
Fire Point	202°C	196°C	186°C	180°C	168°C	170°C

The final phase of this investigation involved testing the elastomer samples in the presence of metal coupons which are indicative of the metallurgy commonly used in Army hydraulic systems (see Table 6). The elastomers were tested for change in hardness (IRHD points) and volume swell, while the metal coupons were monitored for changes in weight (mg/cm^2) and visual signs of corrosion. Weight changes of up to 0.2mg/cm2 are acceptable for magnesium (Mg), aluminum (Al), iron (Fe), and cadmium (Cd), and up to 0.6 mg/cm^2 for copper (Cu). A change in hardness of +10 to -15 IRHD points is acceptable.

Table 6. Elastomer/Metallurgy Compatibility

Seal	ΔVOL%	ΔHARD	ΔWt Cu	ΔWT Mg	ΔWT Al	ΔWT Fe	ΔWT Cd
FVMC	2.8%	-1	0.009	0.014	0.007	0.005	0.005
AU	0.1%	-2	0.014	0.011	0.008	0.020	0.006
NBR	2.4%	+9	0.001	0.012	0.022	0.012	0.018
ACM	2.5%	-1	0.006	0.015	0.027	0.005	0.046
CFM	1.9%	-1	0.001	0.007	0.002	0.001	0.003

As can be seen from Table 6, all coupon weight changes are well within acceptable limits, indicating no incompatibility of SHF with the metallurgy in the presence of different elastomers. The elastomer samples themselves exhibited no significant difference in volume swell in the presence of the metal coupons when compared to results obtained without the presence of coupons. Except for the nitrile, each elastomer sample only exhibited a change in hardness of 1 or 2 points. Referring back to Table 2, it can be seen that these changes in hardness are acceptable in that the baseline results for OHT and FRH are almost identical.

Section 4 Conclusions

From this rather extensive compatibility study, it can be concluded that SHF is entirely compatible in all aspects with current Army hydraulic systems. SHF is completely miscible in OHT and FRH and remains stable in all temperature conditions.[5] Because no appreciable change in corrosion protection or elastomer swell occurs when SHF is combined with OHT or FRH in varying concentrations, hydraulic systems which contain SHF mixed with FRH or OHT can be expected to perform in a satisfactory manner.

Although no incompatibilities have been detected in this study, it is clear that for the sample elastomers investigated, SHF usually provides more seal swell than FRH and less seal swell than OHT. It cannot be determined conclusively that the amount of seal swell delivered by SHF is adequate for all seal materials in all Army vehicles. There still remains the possibility that SHF will cause seals designed for vehicles using FRH to swell too much and seals designed for vehicles using OHT to swell too little. This likelihood is remote, however, based on vehicles currently fielded. Both the M109 Self Propelled Howitzer and the M1A1 Battle Tank make extensive use of nitrile and fluorocarbon seals in their hydraulic systems.[6,7] The M109 utilizes OHT while the M1A1 uses FRH.[8,9] Neither vehicle exhibits problems with either seal leakage or sticking due to too much swell. Since FRH provides sufficient seal swell to prevent leakage and OHT does not cause seals to stick from excessive swelling, it can be concluded that SHF provides adequate seal swell which is neither too excessive or minimal.

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NAVAL AIR WARFARE CTR
1 ATTN CODE PE33 AJD
P O BOX 7176
TRENTON NJ 08628-0176

1 CDR
NAVAL PETROLEUM OFFICE
CAMERON STA T 40
5010 DUKE STREET
ALEXANDRIA VA 22304-6180

1 OFC ASST SEC NAVY (I 7 E)
CRYSTAL PLAZA 5
2211 JEFFERSON DAVIS HWY
ARLINGTON VA 22244-5110

CDR
NAVAL AIR SYSTEMS CMD
1 ATTN AIR 53623C
1421 JEFFERSON DAVIS HWY
ARLINGTON VA 22243-5360

DEPARTMENT OF THE NAVY
U.S. MARINE CORPS

HQ USMC
1 ATTN LPP
WASHINGTON DC 20380-0001

1 PROG MGR COMBAT SER SPT
MARINE CORPS SYS CMD
2033 BARNETT AVE STE 315
QUANTICO VA 22134-5080

1 PROG MGR GROUND WEAPONS
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080

1 PROG MGR ENGR SYS
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080

CDR
MARINE CORPS SYS CMD
1 ATTN SSE
2033 BARNETT AVE STE 315
QUANTICO VA 22134-5010

CDR
BLOUNT ISLAND CMD
1 ATTN CODE 922/1
814 RADFORD BLVD
JACKSONVILLE
FLA 32226-3404

CDR
MARINE CORPS LOGISTICS BA
1 ATTN CODE 837
814 RADFORD BLVD
ALBANY GA 31704-1128

1 CDR
2ND MARINE DIV
PSC BOX 20090
CAMP LEJEUNNE
NC 28542-0090

1 CDR
1ST MARINE DIV
CAMP PENDLETON
CA 92055-5702

1 CDR
FMFPAC G4
BOX 64118
CAMP H M SMITH
HI 96861-4118

DEPARTMENT OF DEFENSE

ODUSD
1 ATTN (L) MRM
PETROLEUM STAFF ANALYST
PENTAGON
WASHINGTON DC 20301-8000

ODUSD
1 ATTN (ES) CI
400 ARMY NAVY DR
STE 206
ARLINGTON VA 22202

HQ USEUCOM
1 ATTN ECJU L1J
UNIT 30400 BOX 1000
APO AE 09128-4209

US CINCPAC
1 ATTN J422 BOX 64020
CAMP H M SMITH
HI 96861-4020

1 JOAP TSC
BLDG 780
NAVAL AIR STA
PENSACOLA FL 32408-5300

DIR DLA
1 ATTN DLA MMDI
ATTN DLA MMSB
CAMERON STA
ALEXANDRIA VA 22304-6100

CDR
DEFENSE FUEL SUPPLY CTR
1 ATTN DFSC Q BLDG 8
1 ATTN DFSC S BLDG 8
CAMERON STA
ALEXANDRIA VA 22304-6160

CDR
DEFENSE GEN SUPPLY CTR
1 ATTN DGSC SSA
1 ATTN DGSC STA
8000 JEFFERSON DAVIS HWY
RICHMOND VA 23297-5678

DIR ADV RSCH PROJ AGENCY
1 ATTN ARPA/ASTO
3701 N FAIRFAX DR
ARLINGTON VA 22203-1714

12 DEFENSE TECH INFO CTR
CAMERON STATION
ALEXANDRIA VA 22314

DEPARTMENT OF AIR FORCE

HQ USAF/LGSSF
1 ATTN FUELS POLICY
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030

HQ USAF/LGTV
1 ATTN VEH EQUIP/FACILITY
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030

AIR FORCE WRIGHT LAB
1 ATTN WL/POS
1 ATTN WL/POSF
1 ATTN WL/POSL
1790 LOOP RD N
WRIGHT PATTERSON AFB
OH 45433-7103

AIR FORCE WRIGHT LAB
1 ATTN WL/MLBT
2941 P ST STE 1
WRIGHT PATTERSON AFB
OH 45433-7750

AIR FORCE WRIGHT LAB
1 ATTN WL/MLSE
2179 12TH ST STE 1
WRIGHT PATTERSON AFB
OH 45433-7718

1 AIR FORCE MEEP MGMT OFC
615 SMSQ/LGTV MEEP
201 BISCAYNE DR STE 2
ENGLIN AFB FL 32542-5303

1 SA ALC/SFT
1014 ANDREWS RD STE 1
KELLY AFB TX 78241-5603

1 WR ALC/LVRS
225 OCMULGEE CT
ROBINS AFB
GA 31098-1647